

Module Title: Metal Corrosion		
Lab compiled by: Tom Stoebe, MatEd Partner	Address:	Email: tgstoebe@earthlink.net
Time to complete module:  15 minutes for set-up 10 minutes for introductory discussion 10 minutes per subsequent class period for observations  <b>Note:</b> As a result of the rather slow reaction rate of corrosion, each sample should be monitored of a course of several days up to a couple weeks. Thus, class time should be utilized throughout the observation process to further discuss each reaction.		
Description of module, lab or demonstration:  Students will explore the corrosion of an assortment of different metals in a variety of environments. Utilizing common household items the corrosion of copper (pennies), steel (nails- standard and galvanized), and aluminum foil is examined and compared against one another. Through this holistic approach, students will develop an understanding for the behavior of each metal during corrosion, as well as, the effect of different manufacturing processes.		
Pre-requisite knowledge and skills:  Although it is not required a general knowledge of corrosion may be beneficial and allow for more detailed discussion relating to observations made during the experimental procedure.		
Materials Category:	Structure of Materials	<input type="checkbox"/>
	Metals	<input checked="" type="checkbox"/>
	Ceramics	<input type="checkbox"/>
	Polymers	<input type="checkbox"/>
	Composites	<input type="checkbox"/>
	Other	<input type="checkbox"/>
Target Grade Level(s) (Check all that apply)	Middle School 6-8	<input checked="" type="checkbox"/>
	High School 9-12	<input checked="" type="checkbox"/>
	Two-year College 13-14	<input checked="" type="checkbox"/>
	Four-year College 15-16	<input checked="" type="checkbox"/>
MatEd core competencies that the training meets:  <ul style="list-style-type: none"> <li>• 7.001 Describe the General Nature of Ferrous Metals</li> <li>• 7.042 Describe the types of flaws that can occur in materials and how they effect properties</li> <li>• 16.003 Describe how defects such as nicks and scratches effect properties of metals and alloys</li> <li>• 16.007 Describe how changes in manufacturing processes effect material properties</li> </ul>		
List of equipment and supplies needed:		

- 10 jars or beakers capable of holding at least 1 to 2 cups (250 to 500 ml)
- Fresh water
- Salt (standard table salt)- to be added to fresh water, approximately .5 grams per cup of water
- 2 Steel nails, 2 to 3 inches in length
- 2 galvanized nails
- 2 standard nails bent 90 degrees
- A vise, hammer, or other means to bend the nails
- 2 copper pennies
- Aluminum foil, enough to place into the small beaker or jar of water
- 30- safety glasses (PPE)
- Optional: 1-2 cups of vegetable oil

**Note:** Supplies listed above are enough to perform one demonstration, if the module is to be used as an in-class laboratory, the appropriate amount of each will be required for each laboratory group

Curriculum overview and notes to instructor:

Corrosion occurs through the oxidation of metals in our environment. Most metals corrode, some more rapidly than others, depending on that environment. Students are familiar with rust, the iron oxide corrosion product of steel. The form and amount of corrosion that occurs depends on factors such as:

- Amount of water in the environment
- Presence of salt or other chemicals
- State of stress of the steel
- Presence of other metals in the environment

In these experiments we test each of these parameters to allow students to experience the variety of results possible. The question on the state of stress relates to the manufacturing process, since different parts of the same product may be produced in the different states of stress.

In general, corrosion will occur where the state of the material is at the highest energy. This is the case for deformed areas. Corrosion will occur at the bent portion of the nail and at the head and point of the nail (nails are formed from wire by an applied stress).

Another effect relates to different metals being present. A galvanized nail has a layer of zinc electro-deposited on it. The zinc is more active than iron, so the zinc will corrode first, protecting the nail from corrosion. Even if there is a break in the galvanized coating, the protection will be present.

	<p>For the Aluminum/ Copper experiment, aluminum is more active than copper, so the aluminum corrodes. The cloudy solution results from the aluminum corrosion products.</p>
<p>Mode of presentation: Hands-on Lab</p>	
<p>Module</p>	<p><b>Abstract:</b>  Rates of corrosion can be affected by many factors including: the environment, stress, oxygen availability, etc. When different metals are in electrical contact, the most active metal corrodes. Steel corrosion produces a variety of iron oxides, depending on conditions. In this experiment, students can observe several of these factors. This experiment requires that students be able to observe the results of corrosion over several days, up to 2 weeks. The samples need to be kept in a safe location for this period, undisturbed but available for observation.</p> <p><b>Experimental Process:</b></p> <ol style="list-style-type: none"> <li>1. Fill 5 beakers part way with fresh water- label as fresh water</li> <li>2. Fill 5 beakers part way with salt water (0.5g of salt per cup of water)- label as salt water</li> <li>3. Introduce one set of the nails into 4 salt water beakers</li> <li>4. Introduce the second set of nails into the fresh water</li> <li>5. In the 5th beaker of fresh water introduce a piece of aluminum foil and then place a penny on top of the aluminum foil</li> <li>6. Repeat step #5 using the salt water beaker</li> </ol> <p>Observe processes of corrosion in each beaker or jar over a period of 1 to 2 weeks. Make notes on each as a function of time. Then answer these questions:</p> <ol style="list-style-type: none"> <li>A. What is the difference between corrosion in salt water as opposed to fresh water?</li> <li>B. What does the galvanizing do?</li> <li>C. Where do the nails corrode the most? Explain.</li> <li>D. What happened to the aluminum foil where it was touched with the copper penny? Why?</li> </ol> <p><b>Further Study:</b></p> <ol style="list-style-type: none"> <li>1. Experiment with other combinations of materials. Some nails are aluminum- how do they behave?</li> <li>2. Carry out the introductory experiment described at <a href="http://www.terrific-scientific.co.uk/Topics/Corrosion/0-introduction.htm">http://www.terrific-scientific.co.uk/Topics/Corrosion/0-introduction.htm</a></li> <li>3. Locate a real example of corrosion in your</li> </ol>

	<p>environment. Research its causes and ways to prevent such corrosion</p> <p>4. Use one beaker with mineral oil instead of water. The lab will then show corrosion and total lack of corrosion.</p> <p>Also, for further observation, while completing the experimental procedure outlined above- it may be beneficial, if an appropriate balance is available, to mass each specimen over the course of the observation process- having students chart the change in mass overtime.</p>
References:	<p>How Stuff Works, Inc. (2007). <i>How does rust work?</i>. Retrieved August 20, 2007 from <a href="http://science.howstuffworks.com/question445.htm">http://science.howstuffworks.com/question445.htm</a>.</p> <p>Terrific Scientific. <i>Corrosion</i>. Retrieved August 20, 2007 from <a href="http://www.terrific-scientific.co.uk/Topics/Corrosion/0-introduction.htm">http://www.terrific-scientific.co.uk/Topics/Corrosion/0-introduction.htm</a>.</p> <p>Wikipedia.org. (2007, August). <i>Rust</i>. Retrieved August 20, 2007 from <a href="http://en.wikipedia.org/wiki/Rust">http://en.wikipedia.org/wiki/Rust</a>.</p> <p>Roberge, P.R. (1999, August). <i>Corrosion doctors</i>. Retrieved August 20, 2007 from <a href="http://www.corrosion-doctors.org/">http://www.corrosion-doctors.org/</a>.</p>
Briefly describe how the effectiveness of the module was evaluated:	<p>The effectiveness of the module was evaluated in "10 Simple and Effective In-class Experiments and Demonstrations for Materials Education." The review provides several notes and observations for the module.</p>
Author Bio:	<p>Dr. Tom Stoebe works with the National Resource Center for Materials Technology Education (MatEd) housed at Edmonds Community College. Dr. Stoebe is a Professor Emeritus in Materials Science and Engineering at the University of Washington and has been at the forefront of materials education in the United States.</p>